



Surge protection concept for LED street lights

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Damage, hazards, risks

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Street lights are currently being retrofitted in German communities and municipal utilities. In this process, conventional luminaires are frequently replaced by LEDs. The reasons for this include, for example, energy efficiency, subsidy programmes, removal of certain lamp technologies from the market and the long lifetime of the new LED technology. To ensure longevity and availability and to avoid unnecessary maintenance, a well-conceived surge protection concept for LED lights should be incorporated at the design stage where the foundations for an efficient protection concept should be laid. Although LED technology has a lot of advantages, it has the disadvantage over older luminaire technologies that replacement costs for equipment are higher and that LEDs are more susceptible to surges.

Surges can be caused by:

- ➔ Direct lightning strike to the luminaire, supply line or periphery of the street light or
- ➔ Indirect lightning strike which causes conducted interference in the supply line as a result of capacitive or inductive coupling or
- ➔ Surges resulting from switching operations, earth faults/ short-circuits or tripping of fuses

An analysis of surge damage to LED street lights shows that in the majority of cases not individual, but several LED lights are affected by the causes mentioned above. Luminaire manufacturers and users such as municipal utilities or communities frequently cannot find the cause of damage. Therefore, the consequences of damage become evident in partial or complete failure of the LED modules, destruction of the LED drivers, reduced brightness or failure of electronic control systems. Even if the LED light is still operational, surges normally negatively affect its lifetime. Consequently, the predicted lifetime cannot be ensured in practice and the LED light must be replaced earlier. These unscheduled costs lead to additional expenses and usually have not been considered in the amortisation of the project. Now the question arises to what extent the manufacturer assumes warranty for the LED light (LED drivers and LED modules). Although the lighting industry already responded to this problem with a higher dielectric strength of the LED drivers of new LED lights, the impulse currents and surges occurring in practice often considerably exceed the typical dielectric strengths of 2 kA to 4 kV of the LED lights many times over. In this case, it must be observed that the types of surges between L to N (differential-mode interference) and L/N to PE (common-mode interference) significantly differ and particularly the cause of damage L/N to PE is often not taken into account by the designer due to the "double or reinforced insulation" (previously class II) of the LED light.

Basic design of street lights in practice and causes of damage

Figure 1 shows the basic design of a street light in practice. Supplied by a transformer station, the individual street light masts are powered by a cable distribution cabinet via a buried cable. A cable junction box with "double or reinforced insulation" (previously class II) with integrated fuses, which supplies the LED light with voltage, is located in the base of the mast,

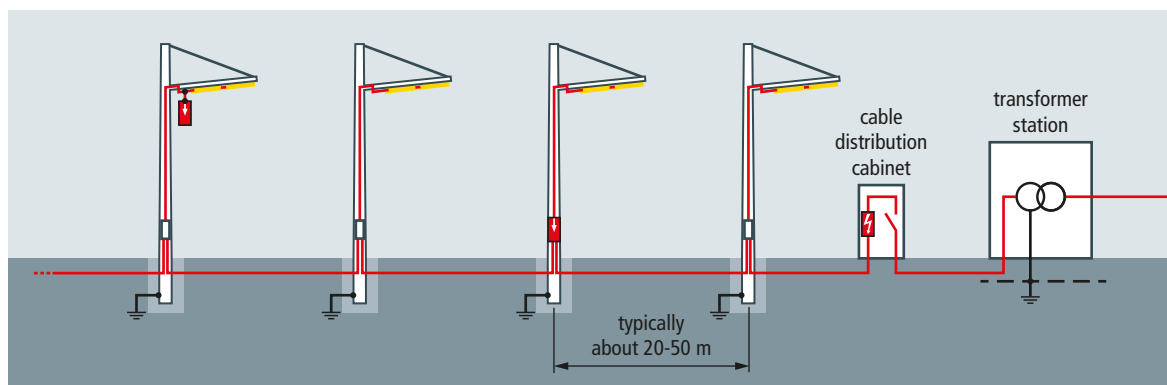


Figure 1 Basic design of street lights in practice

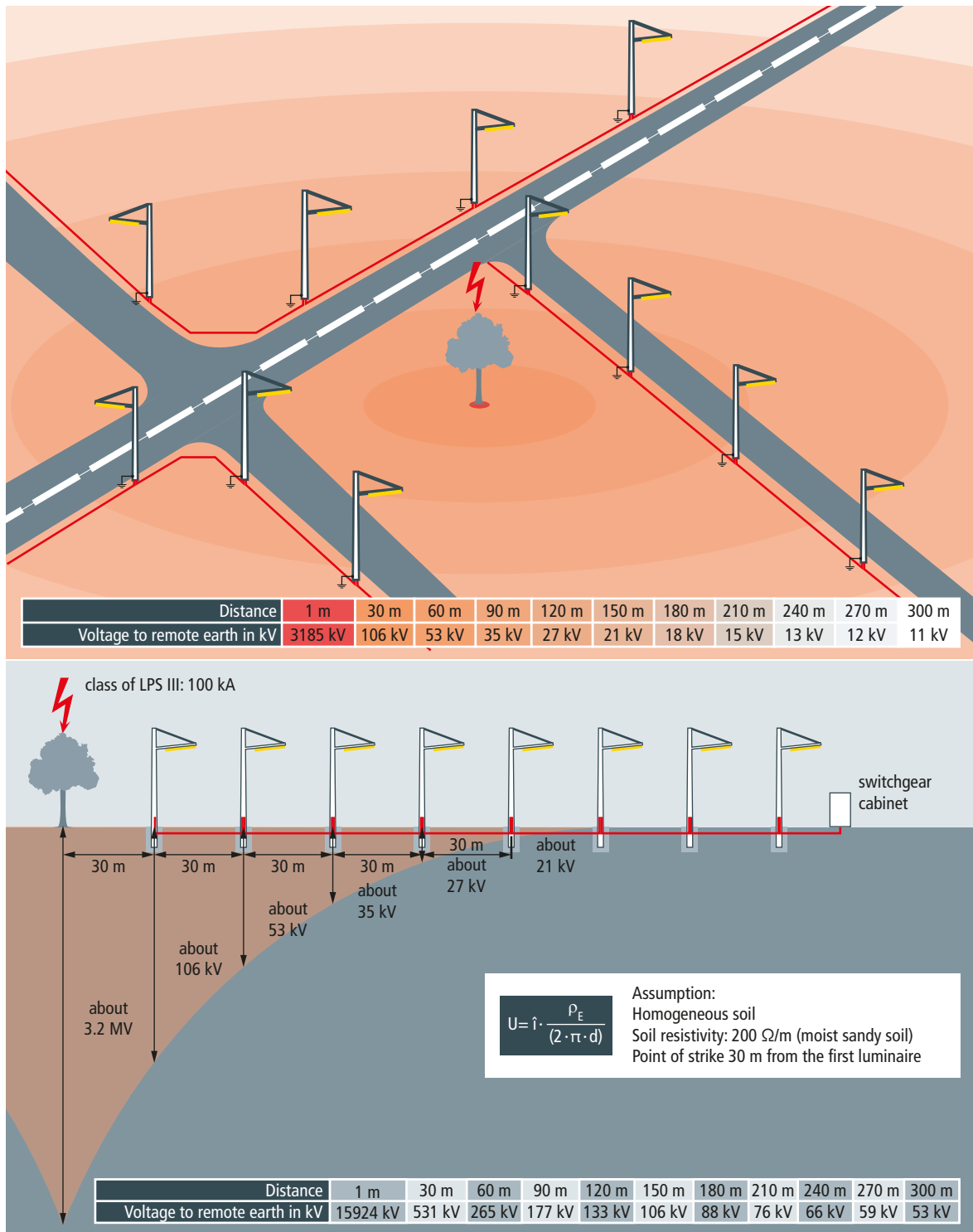


Figure 2 Lightning threat to street lights and potential rise in case of a nearby lightning strike to the street lighting system

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which typically consists of metal. The metal mast itself is either fixed in the soil or by means of a concrete foundation and thus assumes the local potential of the soil. The LED light at the top mostly features "double or reinforced insulation" (previously class II) and consequently does not allow the connection of a protective conductor. A TN-C system with a combined protective and neutral conductor (defined as PEN in the standard) is frequently used for the buried cables of the entire system up to the last luminaire. In the cable junction box, the TN-C system is expanded to a TN-S system and thus one phase and the neutral conductor are led separately to the LED light. In the majority of cases, the PEN or PE conductor is not connected to the metal mast. In this case, the protective conductor must not be connected in the LED light, which can frequently be considered to be an equipment with "double or reinforced insulation" (previously class II).

Practical damage to LED street lights can have different causes. One possible cause is the sensitive LED technology whose susceptibility is comparable to that of electronic components. Moreover, the spatial expansion of the street lighting systems with cables routed up to several hundred metres to the last LED light plays an important role. The cable length is restricted by the disconnection conditions for overcurrent protective devices which must be observed for every single luminaire. In this case, the luminaires do not have a common earth-termination system, but the individual steel masts are accidentally earthed (plastic masts may also be statically charged). However, this leads to different high electrical potentials at the relevant pad

foundations depending on the soil resistivity in case of nearby lightning strikes (Figure 2). Compared to the earth potential at the switchgear cabinet (Figure 2), these high potential differences can exceed the dielectric strength of the LED light integrated in the mast many times over. LED lights with "double or reinforced insulation" (previously class II), which can lead to uncontrolled flashover since they must not be connected to the protective conductor, are commonly used as street lights. Even an existing surge arrester with L → N protection without earth connection in the LED light or cable junction box is not capable of protecting the luminaire from destruction or damage.

Impulse current and impulse voltage tests at LED mast lights

Up to now, a variety of tests was carried out at LED mast lights from different manufacturers in the impulse current laboratory of DEHN + SÖHNE (Figure 3). These tests revealed that the damage to the a.c. terminal compartment of the LED lights (control units) observed in practice can be simulated under laboratory conditions.

The following tests were performed:

a) Combined impulse voltage/impulse current tests (injection to the a.c. connections of the luminaire)

In this case, both common-mode interference (L/N → PE) and differential-mode interference (L → N) were injected into the

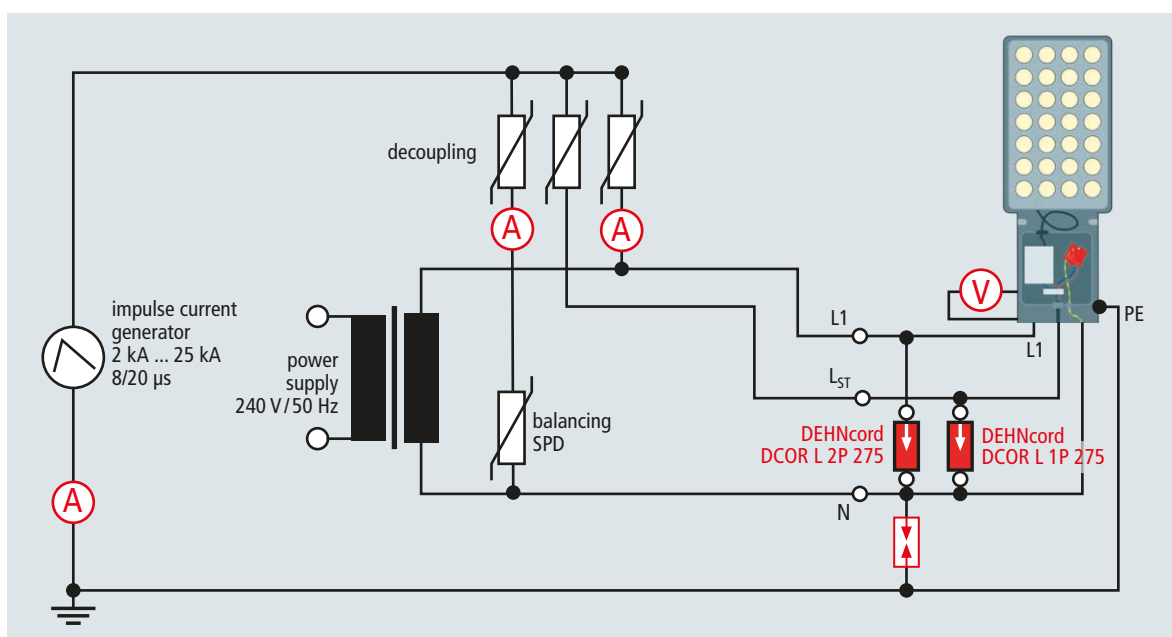


Figure 3 Test setup of an LED light in the laboratory



connecting cables. This revealed that the luminaires have different dielectric strengths. The dielectric strength L → N is typically considerably smaller than the dielectric strength L/N → PE. This is also reflected in the test levels according to IEC 61000-4-5 which must be used for testing the luminaires according to the product standard. However, in case of the L/N → PE interferences, a considerably higher threat can be assumed since these interferences resulting from indirect lightning effects have a significantly higher energy. Common LED mast lights have a typical impulse withstand voltage of between 2 and 4 kV. However, this is not sufficient in many cases due to the exposed outdoor location of LED lights and may lead to higher failure rates in the field.

b) Test with induced currents on the d.c. side and in the LED strings

The following tests were performed to simulate the scenario "injection of impulse currents on the d.c. side and in the LED strings". In the laboratory, an impulse current with an amplitude of 100 kA and an extremely high steepness of about 10 kA/μs is passed by close to the lighting fixture. Even in this extreme test, no direct damage could be simulated apart

from the flickering effects during the test. However, it must be assumed that the equipment subjected to the test is pre-damaged or has a reduced lifetime.

These results reflect the field experiences reported by different LED manufacturers and system operators.

Protection concepts

Figure 4 shows typical places of installation of surge protective devices in an LED mast light:

- ➔ Directly in the LED light
- ➔ In the cable junction box at the mast base
- ➔ In the cable distribution cabinets of the infeed

a) Directly in the LED light

The installation of a compact type 2 surge protective device (according to EN 61643-11) in the LED light considerably increases the dielectric strength of the luminaire to values in the range of 20 kV and thus significantly reduces damage. Thanks to their space-saving design, it is no problem to integrate de-

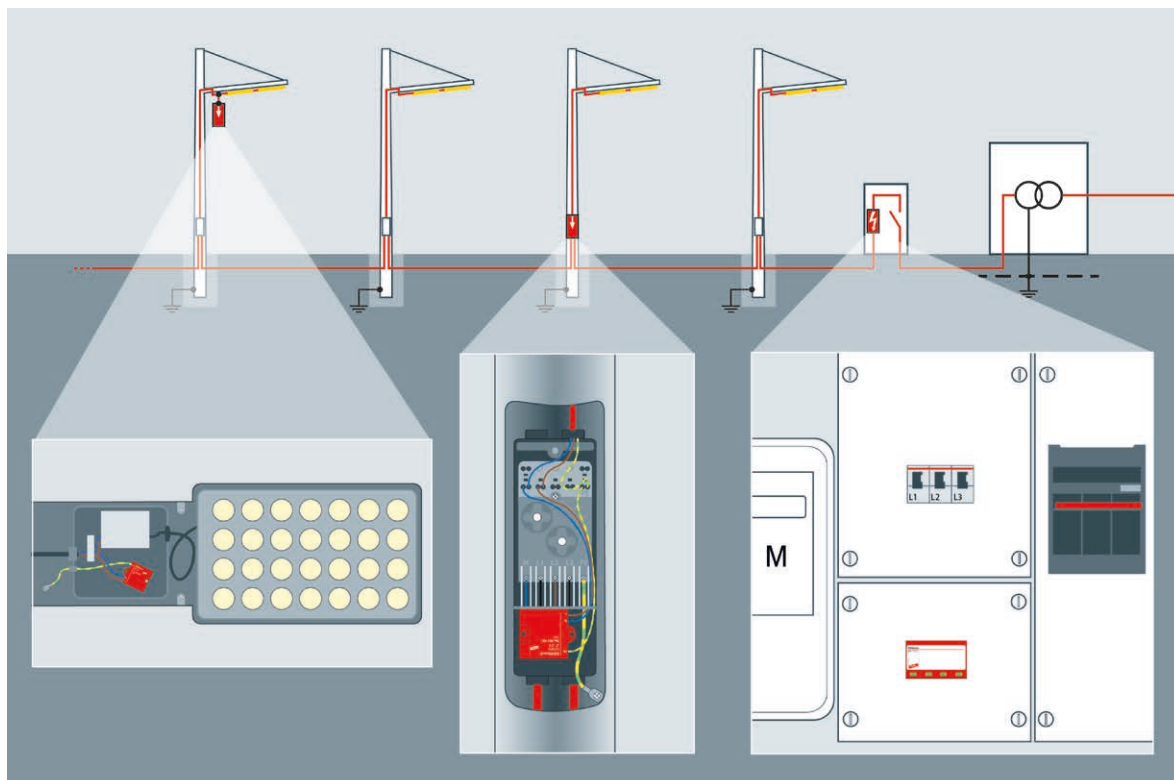


Figure 4 Possible places of installation of surge protective devices in street lighting systems

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Figure 5 Type 2 surge arrester with status indicator



Figure 6 Application-oriented type 1 + type 2 spark-gap-based combined arrester

vices of the DEHncord product line in the terminal compartment of the LED light (**Figure 5**).

At this point it should be mentioned once again that all protective paths, namely L-N, L-PE and N-PE, must be protected by surge protective devices to ensure efficient protection. To this end, a distinction must be made between the protection measures as per IEC 60364-4-41.

This can be easily implemented for luminaires with "automatic disconnection of supply" (previously class I).

For luminaires with "double or reinforced insulation" (previously class II) currently applicable luminaire standards require that a surge protective device must not be connected to the protective conductor or the metal luminaire enclosure in the LED light.

The latest product standard for luminaires (IEC 60598-1) includes the following information on surge protective devices:

- ➔ In case of stationary luminaires of class II, the surge protective devices must not be connected to earth
- ➔ In case of stationary luminaires of class I, the surge protective devices can be removed for testing the dielectric strength
- ➔ Surge protective devices must be tested according to IEC/EN 61643-11

In this case, either only the protective path L-N can be protected, which means a considerable reduction of the protective effect since particularly high-energy interference is to be expected to earth potential, or the surge protective device should be installed in the cable junction box according to case b).

b) In the cable junction box

The cable junction box is ideally suited for integrating surge protective devices. On the one hand, all protective paths (also to earth) can be protected by a surge protective device even if

a lighting fixture with "double or reinforced insulation" (previously class II) is used, thus ensuring maximum protection against transient overvoltages. On the other hand, this area is more easily accessible for retrofitting and maintenance purposes. Moreover, the earth potential of the steel mast can be connected to the cable junction box on the earth side to create a common reference potential.

Depending on the design, different type 2 surge protective devices such as the compact DEHncord arrester or DIN rail mounted devices such as DEHNguard can be installed. A type 1 + type 2 combined arrester, for example DEHNshield, which ensures protection against direct lightning currents, should be installed at this point to provide more efficient protection.

c) In the cable distribution cabinets

To ensure protection against transient overvoltages resulting from indirect lightning effects or switching operations, which are relatively common in the vicinity of the transformer, and against direct lightning effects from the distribution network, it is advisable to install type 1 + type 2 combined arresters in the cable distribution cabinets. Depending on the requirements concerning the lightning current to be discharged, a DEHNventil or DEHNshield arrester (**Figure 6**) can be used.

In addition, the relevant surge protective devices described above should be installed in the vicinity of the LED light they are supposed to protect either at place of installation a (luminaire) or place of installation b (cable junction box).

Verification of the protective circuits in the test laboratory

A complete street lighting system was reproduced in the laboratory (**Figure 7**) to be able to verify the results of the labora-



Figure 7 Test setup for a complete LED street lighting system in the laboratory

tory tests of the LED lights, practical experiences and the resulting practical protection solutions. The test consisted of the following components which can also be found in practice: An LED light typically used for street lighting systems, steel mast, cable junction box and cable distribution cabinet feeding the LED light. Therefore, the simulation in the laboratory is a test under realistic conditions.

Following the test, it was verified that the LED light did not fail in case of direct lightning effects if a cascaded surge protection concept with a coordinated arrester series and a well-conceived earthing concept is used.

Summary

The laboratory tests in cooperation with LED light manufacturers and the practice-oriented system test of a complete LED system - consisting of a cable distribution cabinet, metal mast, cable junction box and LED light – in conjunction with practical experiences are important elements of an efficient protection concept for LED street lighting systems. A well-founded protection concept can only be implemented by means of a complete system consisting of cascaded surge protective devices such as DEHNshield in the cable distribution cabinet and DEHNcord (Figure 5), which is specifically developed for this application, in the cable junction box or in the LED light and a coherent earthing concept where all metal masts must be connected to the protective conductor of the surge protective devices used. This allows to safely control potential differences and ensures the availability of the LED street lighting system also in case of surges. This is the only way to ensure that an investment for retrofitting street lighting systems with the new LED technology achieves the predicted lifetime and uncalculated follow-up costs are prevented.

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